PATENT COOPERATION TREATY

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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

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Applicant's or agent's file reference 38006WOP00	FOR FURTHER ACTION	See Form PCT/IPEA/416
International application No. PCT/AU2004/000316	International filing date (day/month/year) 16 March 2004	Priority date (day/month/year) 17 March 2003

International Patent Classification (IPC) or national classification and IPC

Int. Cl.[7] B03D 1/16, 1/18, 1/20, 1/22

Applicant

OUTOKUMPU OYJ et al

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 3 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. [X] *(sent to the applicant and to the International Bureau)* a total of **17** sheets, as follows:
      - [X] sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      - [ ] sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. [ ] *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) containing a sequence listing and/or table related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).
4. This report contains indications relating to the following items:

[X]	Box No. I	Basis of the report
[ ]	Box No. II	Priority
[ ]	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
[ ]	Box No. IV	Lack of unity of invention
[X]	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
[ ]	Box No. VI	Certain documents cited
[ ]	Box No. VII	Certain defects in the international application
[ ]	Box No. VIII	Certain observations on the international application

Date of submission of the demand	Date of completion of the report
14 January 2005	16 February 2005
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **DAVID K. BELL** Telephone No. (02) 6283 2309

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/AU2004/000316

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ This report is based on translations from the original language into the following language which is the language of a translation furnished for the purposes of:

☐ international search (under Rules 12.3 and 23.1 (b))

☐ publication of the international application (under Rule 12.4)

☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements** of the international application, this report is based on (*replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report*):

☐ The international application as originally filed/furnished

☒ the description:

pages as originally filed/furnished

pages* **1 to 11** received by this Authority on **14 January 2005** with the letter of 14 January 2005

pages* received by this Authority on with the letter of

☒ the claims:

pages as originally filed/furnished

pages* as amended (together with any statement) under Article 19

pages* **12 to 17** received by this Authority on **14 January 2005** with the letter of 14 January 2005

pages* received by this Authority on with the letter of

☒ the drawings:

pages **1/3 to 3/3** as originally filed/furnished

pages* received by this Authority on with the letter of

pages* received by this Authority on with the letter of

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing.

3. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages

☐ the claims, Nos.

☐ the drawings, sheets/figs

☐ the sequence listing (*specify*):

☐ any table(s) related to the sequence listing (*specify*):

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

☐ the description, pages

☐ the claims, Nos.

☐ the drawings, sheets/figs

☐ the sequence listing (*specify*):

☐ any table(s) related to the sequence listing (*specify*):

* *If item 4 applies, some or all of those sheets may be marked "superseded."*

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/AU2004/000316

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1 to 48	YES
	Claims		NO
Inventive step (IS)	Claims	1 to 48	YES
	Claims		NO
Industrial applicability (IA)	Claims	1 to 48	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

D1 = US 5909022
D2 = US 5923012

The invention as defined in the present application is a flotation device in which two flotation tanks are arranged as an upstream tank and a downstream tank where each tank has a slurry feed inlet; a slurry agitation means; a slurry aeration means whereby floatable minerals in suspension float upwards to form a surface froth; an overflow launder for removal of surface froth; a bottom outlet for withdrawal of relatively course or dense material; where the bottom outlet from the upstream tank is connected to the feed inlet of the downstream tank; and at least one of the tanks includes an upper side outlet adapted for withdrawal of a fine fraction of the slurry including a relatively high proportion of fine or lower density components for separate size processing independently of the upstream and downstream tanks.

None of the cited documents either singly, nor in obvious combination, disclose or fairly suggest the invention as defined in the present claims. The claimed invention is therefore novel, has an inventive step and is industrially applicable.

I have searched ☑ and/or examined ☑ the application and prepared my report according to the PCT guidelines and administrative instructions.

Issue	Search Report		1st Exam Opinion/Report		2nd Exam Opinion/Report		3rd Exam Opinion/Report	
	Consid	Not applic	Consid	Not applic	Consid	Not applic	Consid	Not applic
I have considered:								
Novelty	☑	☐	☑	☐	☐	☐	☐	☐
Inventive Step	☑	☐	☑	☐	☐	☐	☐	☐
Unity	☑	☐	☑	☐	☐	☐	☐	☐
Industrial Applicability	☑	☐	☑	☐	☐	☐	☐	☐
Descriptive support	☑	☐	☑	☐	☐	☐	☐	☐
Allowability of amendments	☐	☑	☐	☑	☐	☐	☐	☐
I have conducted an appropriate search:								
I used earlier search results	☑	☐						
I conducted an additonal search	☐	☐						
I conducted an original search using a 3 person team including [3]:	☐	☐						
1. _____								
2. _____								
The application has a valid IPC classification	☑	☐	☑	☐	☐	☐	☐	☐
Comments[4]:								

	Perp Code	Examiner	Date
Search Report	104		31/3/2004
1st Exam Report	104		31/3/2004
2nd Exam Report	104		16/2/2005
3rd Exam Report			

QAG				
Initials:				
Date:				

Notes:

1. Tick LH box if issue considered and objection taken or not taken.
2. Tick RH box if the issue is not applicable for consideration.
3. Enter other members of 3 person team.
4. Supervision, QC, QAG may be noted in comments.

TITLE: A SEPARATE SIZE FLOTATION DEVICE

FIELD OF THE INVENTION

The present invention relates to flotation devices of the type used in mineral separation and will be described hereinafter with reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use.

BACKGROUND OF THE INVENTION

The following discussion of the prior art is intended to place the invention in an appropriate technical context and to allow its benefits to be fully appreciated. Any statements about the prior art should not, however, be considered as admissions that such prior art is widely known or forms part of common general knowledge in the field.

Conventional flotation devices typically include a tank for receiving and containing slurry from a grinding mill, cyclone separator, or the like. An agitator, comprising a rotor housed within a stator, is normally disposed within the tank, and activated via a motor and drive shaft to agitate the slurry. An aeration system is also provided to direct air under pressure into the agitator through a central conduit formed within the drive shaft. Suitable reagents are also added, which coat the surfaces of the mineral particles within the slurry to make the particles hydrophobic and thereby to preferentially promote bubble to particle attachment. As bubbles dispersed by the rotor rise toward the surface of the tank, they carry with them floatable valuable mineral particles, which form a mineral enriched surface froth. The froth then migrates over a lip and into a launder whereby the valuable mineral particles suspended in the froth are recovered from the tank as a mineral concentrate. The gangue particles remaining suspended in the slurry, along with those mineral particles that were not removed by flotation, are continuously discharged from the tank through a bottom outlet. The bottom outlet often incorporates a dart or pinch valve, which is opened to allow the remaining slurry to progress under gravity feed to downstream treatment processes. It is normal practice to control the pulp level in each device using a PID controller, a level indicating probe and a control valve in the form of a dart, pinch or other suitable type of valve.

The slurry that is transferred through the bottom outlet includes both relatively coarse or dense particles as well as a large number of relatively fine particles, including

gangue slimes such as clay minerals, not removed by flotation. The slimes consist of very fine particles and accordingly have a total surface area much greater than that of the coarse particles. Accordingly, when a flotation reagent is added to the outflow from the tank, the majority tends to be absorbed by the slimes, which are not floatable, making the flotation process non-selective. Consequently, most of the coarser valuable particles do not receive sufficient flotation reagent to make them hydrophobic, even given extended conditioning times.

The flotation process can be made more efficient where coarse and fine particles are treated separately and in the past, devices such as hydrocyclones and hydrosizers have been used to separate a flotation feed stream into two discrete streams for separate processing. However, the capital cost of this equipment is high, making the prior art methods uneconomical for all but the most valuable ore bodies.

It is an object of the present invention to overcome or substantially ameliorate one or more disadvantages of the prior art, or at least to provide a useful alternative.

SUMMARY OF THE INVENTION

Accordingly, a first aspect of the present invention provides a flotation device including:

a sequence of at least two flotation tanks arranged relatively as an upstream tank and a downstream tank, each of said tanks being adapted to receive slurry incorporating fine and coarse particles containing minerals to be extracted, and each of said tanks including:

a feed inlet for admission of slurry;

agitation means to agitate the slurry;

aeration means to aerate the slurry whereby floatable minerals in suspension float upwardly to form a surface froth;

an overflow launder for removal of the surface froth; and

a bottom outlet for withdrawal of relatively coarse or dense components of the slurry;

wherein the bottom outlet from the upstream tank is connected to the feed inlet of the downstream tank whereby a relatively dense fraction of the slurry including a relatively high proportion of coarse or dense components is withdrawn from the

upstream tank and fed directly to the downstream tank for reprocessing in the downstream tank; and

wherein at least one of said tanks includes an upper side outlet adapted for withdrawal of a relatively fine fraction of the slurry including a relatively high proportion of fine or lower density components for separate size processing independently of the upstream and downstream tanks.

Preferably the flotation device comprises a sequence of three or more of said tanks connected in series, with the bottom outlet of each tank save for the last being connected to the feed inlet of the tank immediately downstream.

Preferably each of said tanks includes a respective upper side outlet.

Preferably each of said tanks includes a substantially flat base and wherein the bottom outlet of each tank is formed in a sidewall of the tank adjacent the base.

Preferably at least one of said side outlets is adapted to remove slurry containing a relatively high proportion of gangue slimes from the top half of the tank.

Preferably at least one of said side outlets is adapted to remove slurry containing a relatively high proportion of gangue slimes from between a mixing zone of the rotor and a froth zone near the tank surface.

Preferably at least one of said side outlets is adapted to remove slurry from the top third of the tank.

Preferably at least one of said side outlets includes a fluid conduit extending inwardly from the tank sidewall.

Preferably the conduit terminates near the centre of the respective tank, generally proximal a vertical axis thereof.

Preferably at least one of said side outlets directs the lower density components to a separate slurry processing unit configured for optimal treatment of relatively fine particles.

Preferably at least one of said tanks further includes a top substantially hollow deflection cone fixed with respect to the tank and extending generally around the drive shaft.

Preferably at least one of said tanks further includes a fluid conduit extending through a sidewall of the top cone to the respective side outlet to facilitate fluid transfer from within the top cone to the side outlet.

Preferably said at least one tank further includes a bottom substantially hollow deflection cone, also extending generally around the drive shaft, at a position below said top deflection cone.

Preferably the bottom cone is axially movable relative to the drive shaft to allow an area of an annular opening between the top and bottom cones to be selectively adjusted.

Preferably a lower end of the top cone is nested at least partially within an upper end of the bottom cone.

Preferably the top cone is truncated and includes an opening at its lowermost end.

Preferably the lowermost end of the bottom cone fits relatively closely around the drive shaft, thereby substantially to impede slurry flow through a region between the lowermost end of the bottom cone and the drive shaft.

Preferably the agitation means of each of said tanks includes a rotor supported for rotation within a surrounding stator, and operable by means of a central drive shaft extending downwardly into the respective tank.

Preferably the aeration means of each of said tanks includes an air blower and a fluid conduit for directing air from the blower into the respective agitation means.

Preferably the fluid conduit of the aeration means includes an axial bore extending through the drive shaft of the respective rotor.

Preferably each of said tanks is generally in the shape of a right circular cylinder.

Preferably the bottom outlet of each of said tanks is defined by an opening in the lower half of the tank.

Preferably the opening defining the bottom outlet of each of said tanks is defined in the respective tank sidewall adjacent the tank floor.

Preferably the opening defining the bottom outlet of each of said tanks is defined in the respective tank floor adjacent the tank sidewall.

Preferably the flotation device includes a plurality of downstream tanks connected in series, each configured for optimal treatment of a slurry including a relatively high proportion of relatively coarse or dense components and each having an inlet connected to the bottom outlet of its adjacent upstream tank.

Preferably all of the downstream tanks are substantially identical, with each tank including a side outlet for withdrawal of relatively lower density components of the slurry from an adjacent upstream tank.

Preferably a side outlet of each tank directs lower density slurry components to a separate slurry processing unit configured for optimal treatment of relatively fine particles.

Preferably only the third and subsequent tanks in the series include a side outlet for withdrawal of relatively lower density components of the slurry from the tank.

Preferably a plurality of said tanks is arranged in pairs, wherein the level of the base of each successive tank pair is lower than the base of its adjacent upstream pair, such that slurry flows under the influence of gravity from one tank pair to the next.

Preferably the plurality of tanks is arranged in groups of more than two, wherein the level of the base of each successive tank group is lower than the base of the adjacent upstream group, such that slurry flows under the influence of gravity from one tank group to the next.

Preferably the outlet from one tank pair to the adjacent downstream tank pair includes a valve to allow discharge of the relatively coarse or dense components of the slurry.

Preferably the valve is a dart valve.

Preferably the valve is positioned substantially within the tank adjacent the outlet.

Preferably the valve is positioned in a conduit extending between adjoining tanks.

Preferably each tank has a capacity of at least $100m^3$.

Preferably the slurry entering said upstream tank via the feed inlet includes less than around 55% solids.

Preferably the agitation means of each tank is aligned with the respective feed inlet, such that feed slurry entering the tank flows directly into the agitation means.

A second aspect of the invention provides a method of separate size flotation including the steps of:

providing a flotation device according to the first aspect of the invention;

directing a feed slurry into the flotation device through the feed inlet of the upstream tank;

withdrawing the relatively dense fraction of the slurry through the bottom outlet of the upstream tank and feeding that fraction through the feed inlet of the downstream tank, for reprocessing in the downstream tank; and

withdrawing the relatively fine fraction of the slurry through the side outlet for separate size processing independently of the upstream and downstream tanks.

Preferably after withdrawal through the side outlet, the relatively fine fraction of the slurry is directed into one or more downstream fine particle flotation tanks specifically configured for optimal recovery of relatively fine particles.

Preferably after withdrawal from the tank and where the fine particles are predominantly gangue slimes, they are discarded.

Preferably after withdrawal from the tank, the relatively coarse or dense components are directed into a separate series of one or more downstream coarse particle flotation tanks.

Preferably the method includes the steps of providing a sequence of three or more of said tanks, and connecting said tanks in series with the bottom outlet of each tank save for the last being connected to the feed inlet of the tank immediately downstream.

Preferably the method includes the further step of providing each of said tanks with a respective upper side outlet.

Preferably the method includes the further step of positioning each downstream tank at a level below the tank immediately upstream thereof, to facilitate gravity feed of slurry through the series of tanks.

Preferably the method includes the step of adding a flotation reagent to the slurry in the downstream tanks.

Preferably the method includes the step of diluting the slurry in the downstream tanks.

Preferably the tanks have a capacity of at least $100m^3$.

Preferably the feed slurry includes less than around 55% solids.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic cross-sectional side elevation showing a flotation device according to the invention;

Figure 2 is a schematic view showing a network of the flotation devices; and

Figure 3 is a schematic view of an alternative network arrangement.

PREFERRED EMBODIMENTS OF THE INVENTION

The illustrated flotation device is adapted for use in extracting valuable minerals from the cyclone overflow from a grinding circuit. This overflow is in the form of a slurry and typically includes mineral particles having a P80 of between around 50μm to around 220μm. However, the slurry also contains gangue slimes, which contain few recoverable valuable minerals, but which tend to absorb a high proportion of flotation reagents that are added to the slurry to facilitate recovery of the valuable minerals. It is emphasised that the illustrated flotation device differs from other flotation devices, such as flash flotation cells or "Skim Air" cells, which are typically located upstream in the grinding mill circuit and are used to process slurries containing much coarser particles and also having a higher percentage of solids. Typically, Skim Air cells are used to process slurries containing around 65% solids, whereas the illustrated flotation device is configured to process slurries with up to around 50% to 55% solids. It is also noted that Skim Air cells are configured to cause around 70% to 80% of the solids to bypass the rotor. This 70% to 80% of solids contains most of the coarse material from the feed slurry, which if fed into the rotor causes significant rotor wear. However, in conventional cells, such as those shown in the drawings, the feed slurry contains much smaller particles, and accordingly, the slurry is caused to pass directly through the rotor.

Referring to the drawings, the invention provides a flotation device including a tank 1 containing a slurry incorporating minerals to be extracted. Typically, the tank would have a capacity of at least $100m^3$, however in some alternative embodiments, smaller tanks are used. The tank includes a generally flat base 2 and a substantially cylindrical sidewall 3 extending upwardly from the base. A peripheral overflow launder 4 extends around the inside top of the sidewall for removing mineral enriched froth as it floats to the surface.

An agitator is disposed to agitate the slurry within the tank. The agitator includes a rotor 5 mounted on a centrally disposed drive shaft 6 extending axially downwardly into the tank and driven by a motor 7. A stator 8 is also provided around the rotor. As shown in the drawings, the rotor is located close to the floor of the tank, such that when feed slurry enters the tank it flows directly through the rotor.

Axially spaced top and bottom hollow froth deflection cones 9 and 10 are also provided. The cone sidewalls extend around the drive shaft adjacent the top of the tank and each cone is oriented such that its smallest diameter is located at its lowermost end nearest the rotor 5. The top cone 9 is truncated and includes an opening 11 at its lowermost end. However, the lowermost end 12 of the bottom cone fits relatively closely around the drive shaft 6, substantially to prohibit slurry flow through this region.

The top cone is fixed with respect to the tank and the lower cone 10 is axially movable along the drive shaft 6 to allow the area of an annular opening 12 between the partially nested cones to be adjusted. In use, the lower cone 10 is moved toward the rotor 5 to increase the area of the opening or away from the rotor to reduce the area of the opening 12.

The flotation device further includes an aeration system including an air blower and a fluid conduit (not shown) to direct air from the blower into the agitator. The conduit is defined in part by an axial bore (not shown) extending through the drive shaft 6 of the rotor.

Feed slurry is introduced into the tank 1 through a feed inlet 13 formed in the sidewall of the tank. A bottom outlet 14 is formed in the lower portion of the tank sidewall 3 to allow removal of relatively coarse or dense components of the slurry. A side outlet 15 is provided to remove slurry containing a relatively high proportion of the gangue slimes for separate downstream treatment. The side outlet includes a fluid conduit 16 connected to the top cone 9. The conduit passes through a slot (not shown) in the sidewall of the bottom cone. A flexible seal (not shown) is provided around the conduit 16 to seal the slot. The conduit is located in the top third of the tank and is adapted to remove slurry from within the top deflection cone 9. The side outlet also includes a valve (not shown) to control flow of fluid from the top cone. The valve can be a pinch valve, or may be a weir type arrangement, or any other suitable alternative.

As will be appreciated by those skilled in the art, particle size distribution varies within the tank based on the initial composition of the slurry, and relevant system parameters such as tank geometry, aeration rate and the normal operating speed of the agitator. Moreover, it is known that the gangue slimes present in the slurry do not float, despite the fact that they absorb a significant amount of the flotation reagents added to the slurry to facilitate recovery of the valuable mineral particles. Accordingly, the size and location of the opening 12 between the deflection cones is adjusted on the basis of these parameters and the flotation kinetics of the gangue slimes to correspond with a position within the tank having a relatively high concentration of gangue slimes. This position is above a mixing zone of the rotor and below a froth zone near the top of the tank. Adjusting the area of the opening controls the fluid velocity through the opening, and hence the size range of particles entering the bottom cone 10. In this way, the system can be optimised to remove a majority of the gangue slimes through the side outlet without loss of valuable minerals.

Turning now to describe the operation of the flotation device in more detail, slurry is initially fed into the tank via feed inlet 13, from where it migrates toward the agitation and aeration assemblies positioned near the bottom of the tank. The action of the rotor 5 induces a primary flow through the slurry as indicated by arrows F1. The primary flow continuously recirculates the slurry at the bottom of the tank to maintain the particles in suspension. The aeration system continuously disperses air into the rotor 5 to form fine bubbles which collide with and adhere to the valuable mineral particles in the slurry and subsequently float to the top of the tank to form a mineral enriched surface froth. As the froth floats toward the surface, it is directed radially outwardly by the deflection cones for recovery through the overflow launder 4. The rotor also induces a secondary flow through the slurry as indicated by arrows F2.

As targeted finer particles move in the direction indicated by arrows F2, they are drawn into the opening 12 between the deflection cones. From there, they pass downwardly through the bottom cone 10, up through the opening 11 in the top cone, through conduit 16 and out through the side outlet 15. The fine particles are processed downstream separately from the outflow from the bottom outlet 14. Simultaneously, due to their buoyancy and upward velocity, valuable mineral particles which have become

attached to bubbles from the aeration system rise into the froth zone near the top of the tank for recovery via the overflow launder.

Any gangue particles remaining suspended in the slurry, along with those mineral particles that were not removed by flotation, are continuously discharged from the tank through the bottom outlet 14. From there, the coarse particles are directed initially into a second tank that is substantially identical to the first tank.

In the embodiment illustrated in Figure 2, this second tank includes a base 2 located at a lower level than the base of the first tank such that slurry feeds into the second tank under gravity. From the second tank, the slurry flows under gravity into a plurality of substantially similar downstream tanks, each connected in series. Respective dart valves 17 control flow of slurry between adjacent tanks.

In the embodiment illustrated in Figure 3, the second tank is located at the same level, such that the first and second tanks define a first tank pair. From the second tank, the slurry flows under the influence of gravity into a plurality of downstream tank pairs, each substantially identical to the first pair. Flow of slurry between the tank pairs is controlled by respective dart valves 17, which are continuously adjusted to maintain the pulp level in the cell. As shown in Figure 3, the base of each subsequent tank pair is lower than that of the adjacent upstream tank pair.

It will be appreciated that in alternative embodiments, the tanks may be disposed at the same level and the slurry may be pumped between the tanks. Also, in some situations, it may be preferable to include side outlets on only some of the downstream tanks. It will also be appreciated that hybrid and other network combinations, including tanks connected in series, parallel or a combination of both, may be employed, as required. It will further be understood that different valve types, and different forms of conduit between the tanks, may alternatively be used. In still further embodiments, the aeration system may supply air to the rotor through a pipe with a discharge point located underneath the rotor. In yet another embodiment, such as that illustrated in Figure 3, the deflection cones are omitted and the conduit 16 extends from the side outlet 15 to terminate at a position in the top third of the tank, near the drive shaft 6.

In the illustrated embodiments, it will be appreciated that the outflow slurry from each tank has a higher proportion of coarser particles than was present in the inflow slurry from the upstream tanks, since some of the finer particles are removed through the

side outlets 15. Accordingly, the proportion of coarse particles in the slurry increases as the feed liquid migrates progressively through the network of tanks. Consequently, when a flotation reagent is added to the slurry in the downstream tanks, there is a greater probability of coating some of the larger particles. Therefore, the probability of floating these larger particles increases in the downstream tanks. This in turn increases the overall efficiency of the flotation process.

As described above, the flotation device permits a slurry stream containing both fine and coarse particles to be separated progressively into two parallel branches, with one branch containing the relatively coarse particles from the stream and the other branch containing the finer particles. In this way, the two branches can be individually optimised for the treatment of either coarse or fine particles, which optimises the efficiency and cost effectiveness of the overall separation process. It will therefore be appreciated that the invention provides both practical and commercially significant advantages over the prior art.

While the invention has been described with reference to conventional flotation cells, it will be appreciated that the same principles may be applied to other flotation cells, such as flash flotation cells, or Skim Air cells. Moreover, although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

CLAIMS

1. [AMENDED] A flotation device including:

a sequence of at least two flotation tanks arranged relatively as an upstream tank and a downstream tank, each of said tanks being adapted to receive slurry incorporating fine and coarse particles containing minerals to be extracted, and each of said tanks including:

a feed inlet for admission of slurry;

agitation means to agitate the slurry;

aeration means to aerate the slurry whereby floatable minerals in suspension float upwardly to form a surface froth;

an overflow launder for removal of the surface froth; and

a bottom outlet for withdrawal of relatively coarse or dense components of the slurry;

wherein the bottom outlet from the upstream tank is connected to the feed inlet of the downstream tank whereby a relatively dense fraction of the slurry including a relatively high proportion of coarse or dense components is withdrawn from the upstream tank and fed directly to the downstream tank for reprocessing in the downstream tank; and

wherein at least one of said tanks includes an upper side outlet adapted for withdrawal of a relatively fine fraction of the slurry including a relatively high proportion of fine or lower density components for separate size processing independently of the upstream and downstream tanks.

2. [AMENDED] A flotation device according to claim 1, comprising a sequence of three or more of said tanks connected in series, with the bottom outlet of each tank save for the last being connected to the feed inlet of the tank immediately downstream.

3. [AMENDED] A flotation device according to claim 1 or claim 2, wherein each of said tanks includes a respective upper side outlet.

4. [AMENDED] A flotation device according to any one of the preceding claims, wherein each of said tanks includes a substantially flat base and wherein the bottom outlet of each tank is formed in a sidewall of the tank adjacent the base.

5. [AMENDED] A flotation device according to any one of the preceding claims, wherein at least one of said side outlets is adapted to remove slurry containing a relatively high proportion of gangue slimes from the top half of the tank.

6. [AMENDED] A flotation device according to any one of the preceding claims, wherein at least one of said side outlets is adapted to remove slurry containing a relatively high proportion of gangue slimes from between a mixing zone of the rotor and a froth zone near the tank surface.

7. [AMENDED] A flotation device according to any one of the preceding claims, wherein at least one of said side outlets is adapted to remove slurry from the top third of the tank.

8. [AMENDED] A flotation device according to any one of the preceding claims, wherein at least one of said side outlets includes a fluid conduit extending inwardly from the tank sidewall.

9. [AMENDED] A flotation device according to claim 8, wherein the conduit terminates near the centre of the respective tank, generally proximal a vertical axis thereof.

10. [AMENDED] A flotation device according to any one of the preceding claims, wherein at least one of said side outlets directs the lower density components to a separate slurry processing unit configured for optimal treatment of relatively fine particles.

11. [AMENDED] A flotation device according to any one of the preceding claims, wherein at least one of said tanks further includes a top substantially hollow deflection cone fixed with respect to the tank and extending generally around the drive shaft.

12. [AMENDED] A flotation device according to claim 11, wherein at least one of said tanks further includes a fluid conduit extending through a sidewall of the top cone to the respective side outlet to facilitate fluid transfer from within the top cone to the side outlet.

13. [AMENDED] A flotation device according to claim 11 or claim 12,wherein said at least one tank further includes a bottom substantially hollow deflection cone, also extending generally around the drive shaft, at a position below said top deflection cone.

14. [AMENDED] A flotation device according to claim 13, wherein the bottom cone is axially movable relative to the drive shaft to allow an area of an annular opening between the top and bottom cones to be selectively adjusted.

15. [AMENDED] A flotation device according to claim 13 or claim 14, wherein a lower end of the top cone is nested at least partially within an upper end of the bottom cone.

16. [AMENDED] A flotation device according to any one of claims 11 to 15, wherein the top cone is truncated and includes an opening at its lowermost end.

17. [AMENDED] A flotation device according to any one of claims 11 to 16, wherein the lowermost end of the bottom cone fits relatively closely around the drive shaft, thereby substantially to impede slurry flow through a region between the lowermost end of the bottom cone and the drive shaft.

18. [AMENDED] A flotation device according to any one of the preceding claims, wherein the agitation means of each of said tanks includes a rotor supported for rotation within a surrounding stator, and operable by means of a central drive shaft extending downwardly into the respective tank.

19. [AMENDED] A flotation device according to any one of the preceding claims, wherein the aeration means of each of said tanks includes an air blower and a fluid conduit for directing air from the blower into the respective agitation means.

20. [AMENDED] A flotation device according to claim 16, wherein fluid conduit of the aeration means includes an axial bore extending through the drive shaft of the respective rotor.

21. [AMENDED] A flotation device according to any one of the preceding claims, wherein each of said tanks is generally in the shape of a right circular cylinder.

22. [AMENDED] A flotation device according to any one of the preceding claims, wherein the bottom outlet of each of said tanks is defined by an opening in the lower half of the tank.

23. [AMENDED] A flotation device according to claim 22, wherein the opening defining the bottom outlet of each of said tanks is defined in the respective tank sidewall adjacent the tank floor.

24. [AMENDED] A flotation device according to claim 22, wherein the opening defining the bottom outlet of each of said tanks is defined in the respective tank floor adjacent the tank sidewall.

25. [AMENDED] A flotation device according to any one of the preceding claims, including a plurality of downstream tanks connected in series, each configured for optimal treatment of a slurry including a relatively high proportion of relatively coarse or dense components and each having an inlet connected to the bottom outlet of its adjacent upstream tank.

26. [AMENDED] A flotation device according to claim 25, wherein all of the downstream tanks are substantially identical, with each tank including a side outlet for

withdrawal of relatively lower density components of the slurry from an adjacent upstream tank.

27. [AMENDED] A flotation device according to claim 25 or claim 26, wherein a side outlet of each tank directs lower density slurry components to a separate slurry processing unit configured for optimal treatment of relatively fine particles.

28. [AMENDED] A flotation device according to claim 25 or claim 26, wherein only the third and subsequent tanks in the series include a side outlet for withdrawal of relatively lower density components of the slurry from the tank.

29. [AMENDED] A flotation device according to any one of claims 25 to 28, wherein a plurality of said tanks is arranged in pairs, wherein the level of the base of each successive tank pair is lower than the base of its adjacent upstream pair, such that slurry flows under the influence of gravity from one tank pair to the next.

30. [AMENDED] A flotation device according to any one of claims 25 to 28, wherein the plurality of tanks is arranged in groups of more than two, wherein the level of the base of each successive tank group is lower than the base of the adjacent upstream group, such that slurry flows under the influence of gravity from one tank group to the next.

31. [AMENDED] A flotation device according to claim 29, wherein the outlet from one tank pair to the adjacent downstream tank pair includes a valve to allow discharge of the relatively coarse or dense components of the slurry.

32. [AMENDED] A flotation device according to claim 31, wherein the valve is a dart valve.

33. [AMENDED] A flotation device according to claim 32, wherein the valve is positioned substantially within the tank adjacent the outlet.

34. [AMENDED] A flotation device according to claim 32, wherein the valve is positioned in a conduit extending between adjoining tanks.

35. [AMENDED] A flotation device according to any one of the preceding claims, wherein each tank has a capacity of at least $100m^3$.

36. [AMENDED] A flotation device according to any one of the preceding claims, wherein the slurry entering said upstream tank via the feed inlet includes less than around 55% solids.

37. [AMENDED] A flotation device according to any one of the preceding claims, wherein the agitation means of each tank is aligned with the respective feed inlet, such that feed slurry entering the tank flows directly into the agitation means.

38. [AMENDED] A method of separate size flotation including the steps of:

providing a flotation device as defined in any one of claims 1 to 37;

directing a feed slurry into the flotation device through the feed inlet of the upstream tank;

withdrawing the relatively dense fraction of the slurry through the bottom outlet of the upstream tank and feeding that fraction through the feed inlet of the downstream tank, for reprocessing in the downstream tank; and

withdrawing the relatively fine fraction of the slurry through the side outlet for separate size processing independently of the upstream and downstream tanks.

39. [AMENDED] A method according to claim 38, wherein after withdrawal through the side outlet, the relatively fine fraction of the slurry is directed into one or more downstream fine particle flotation tanks specifically configured for optimal recovery of relatively fine particles.

40. [AMENDED] A method according to claim 39, wherein after withdrawal from the tank and where the fine particles are predominantly gangue slimes, they are discarded.

41. [AMENDED] A method according to any one of claims 38 to 40, wherein after withdrawal from the tank, the relatively coarse or dense components are directed into a separate series of one or more downstream coarse particle flotation tanks.

42. [AMENDED] A method according to any one of claims 38 to 41, including the steps of providing a sequence of three or more of said tanks, and connecting said tanks in series with the bottom outlet of each tank save for the last being connected to the feed inlet of the tank immediately downstream.

43. [AMENDED] A method according to claim 42, including the further step of providing each of said tanks with a respective upper side outlet.

44. [AMENDED] A method according to any one of claims 38 to 43, including the further step of positioning each downstream tank at a level below the tank immediately upstream thereof, to facilitate gravity feed of slurry through the series of tanks.

45. [AMENDED] A method according to any one of claims 38 to 44, including the step of adding a flotation reagent to the slurry in the downstream tanks.

46. [AMENDED] A method according to any one of claims 38 to 45, including the step of diluting the slurry in the downstream tanks.

47. [AMENDED] A method according to any one of claims 38 to 46, wherein the tanks have a capacity of at least $100m^3$.

48. [AMENDED] A method according to any one of claims 38 to 47, wherein said feed slurry includes less than around 55% solids.